

## LT4295, LT4321

# High Efficiency IEEE 802.3bt (PoE++, Type 4, 62W/71W) PD with Flyback DC/DC Converter and Auxiliary Supply Input

## DESCRIPTION

Demonstration Circuit 2476A is an IEEE 802.3bt (Draft 2.2) compliant power over ethernet (PoE) powered device (PD). It features the [LT®4295](#) PD interface and switching regulator controller and the [LT4321](#) PoE ideal diode bridge controller.

The LT4295 provides IEEE 802.3af (PoE, Type 1), IEEE 802.3at (PoE+, Type 2), and IEEE 802.3bt (PoE++, Type 3 and 4) compliant interfacing and power supply control. It utilizes an external, low  $R_{DS(on)}$  (30m $\Omega$  typical) N-channel FET for the hot swap function to improve efficiency. The LT4295 controls a DC/DC converter that utilizes a highly efficient flyback topology with synchronous rectification.

The LT4321 controls eight low  $R_{DS(on)}$  (30m $\Omega$  typical) N-channel FETs to further improve end-to-end power

delivery efficiency and ease thermal design. This solution replaces the eight diodes typically found in a passive PoE rectifier bridge.

The DC2476A-A accepts up to 71W of delivered power from a power sourcing equipment (PSE) via the RJ45 connector (J1) or a local 48V DC power supply using the auxiliary supply input. When both supplies are connected, the auxiliary supply input has priority over the PoE input. The DC2476A-A supplies a 24V output at up to 2.7A.

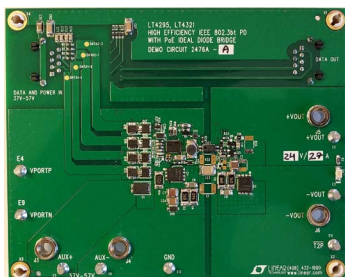
**Design files for this circuit board are available at <http://www.linear.com/demo/DC2476A-A>**

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## PERFORMANCE SUMMARY

| PARAMETER                    | CONDITIONS                                       | VALUE                          |
|------------------------------|--|--------------------------------|
| Port Voltage ( $V_{PORT}$ )  | At RJ45  | 37V to 57V                     |
| Auxiliary Voltage            | From AUX+ to AUX- Terminals                      | 37V to 57V                     |
| Output Voltage ( $V_{OUT}$ ) |  | 24V (Typical)                  |
| Output Current ( $I_{OUT}$ ) |  | 2.7A (Max)                     |
| Output Voltage Ripple        | $V_{PORT} = 41.2V$ , $I_{OUT} = 2.7A$            | 200mV <sub>P-P</sub> (Typical) |
| Load Regulation              |  | 0.5% (Typical)                 |
| Efficiency                   | $V_{PORT} = 50V$ , $I_{OUT} = 2.7A$ , End-to-End | 91.5% (Typical)                |
| Switching Frequency          |  | 250kHz (Typical)               |

## BOARD PHOTO

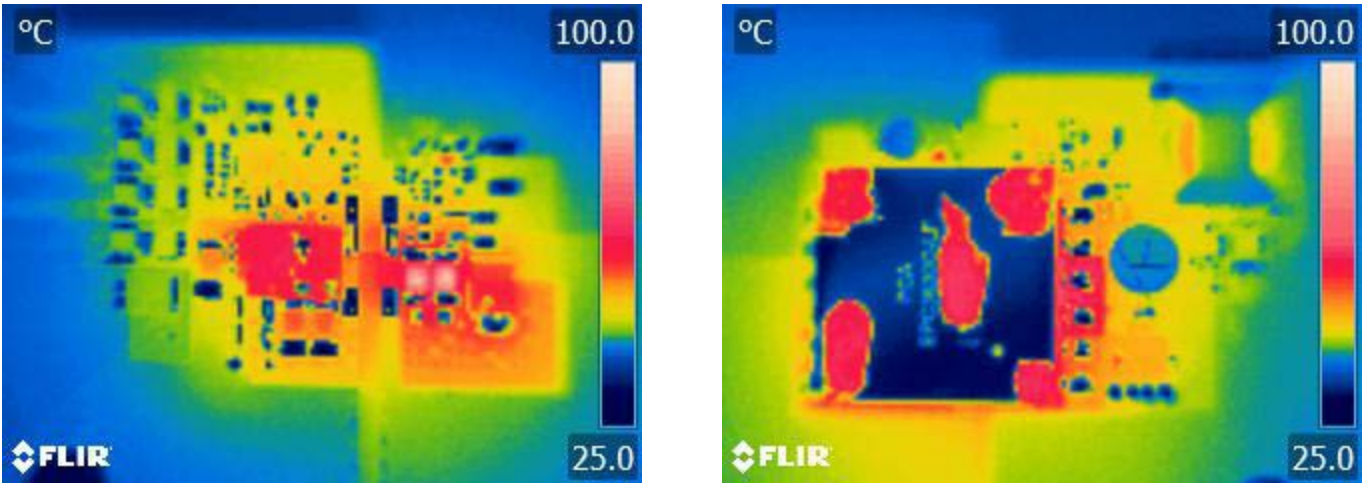


Top Side



Bottom Side

TYPICAL PERFORMANCE CHARACTERISTICS



Top Side  
Bottom Side  
Figure 1. Thermal Pictures (Conditions:  $V_{PORT} = 57V$ ,  $V_{OUT} = 24V$ ,  $I_{OUT} = 2.7A$ )

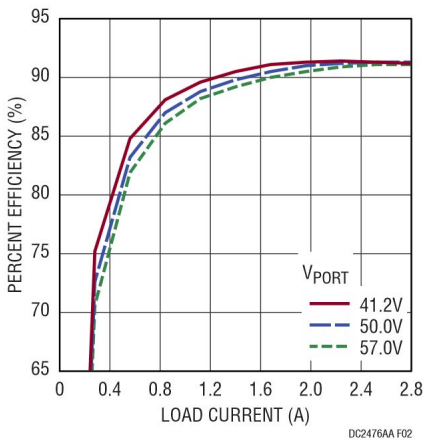


Figure 2. Efficiency (End-to-End)

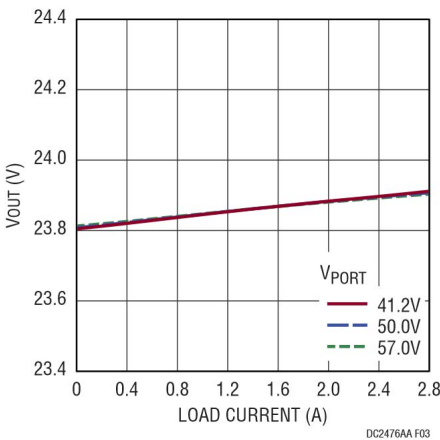


Figure 3. Load Regulation

TYPICAL PERFORMANCE CHARACTERISTICS

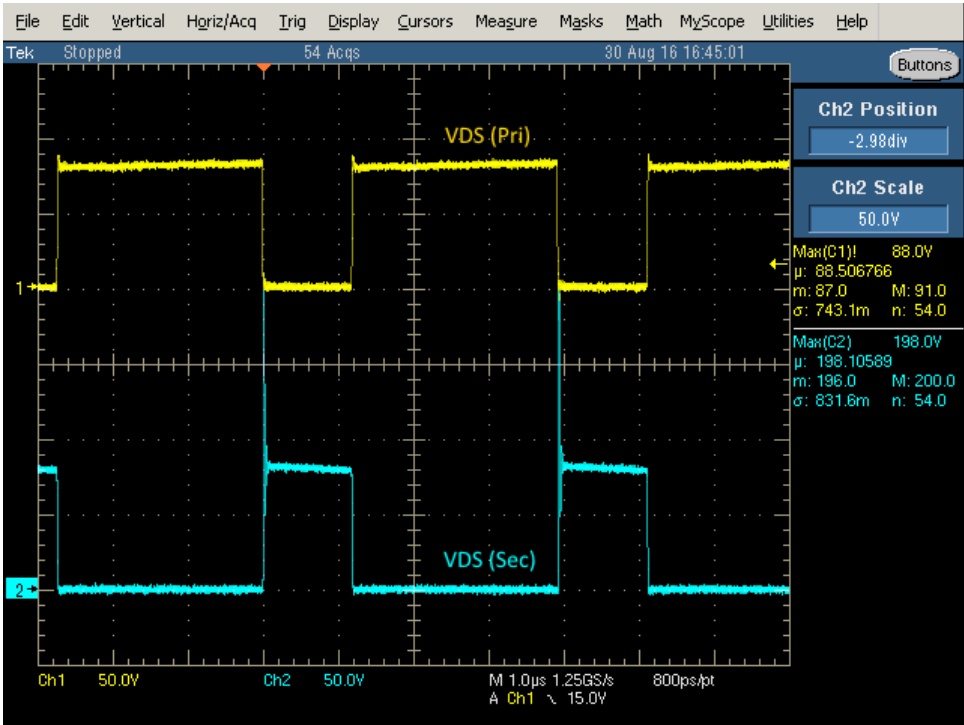


Figure 4. Switch Node Waveforms (Conditions:  $V_{PORT} = 57V$ ,  $V_{OUT} = 24V$ ,  $I_{OUT} = 2.7A$ )

TYPICAL PERFORMANCE CHARACTERISTICS

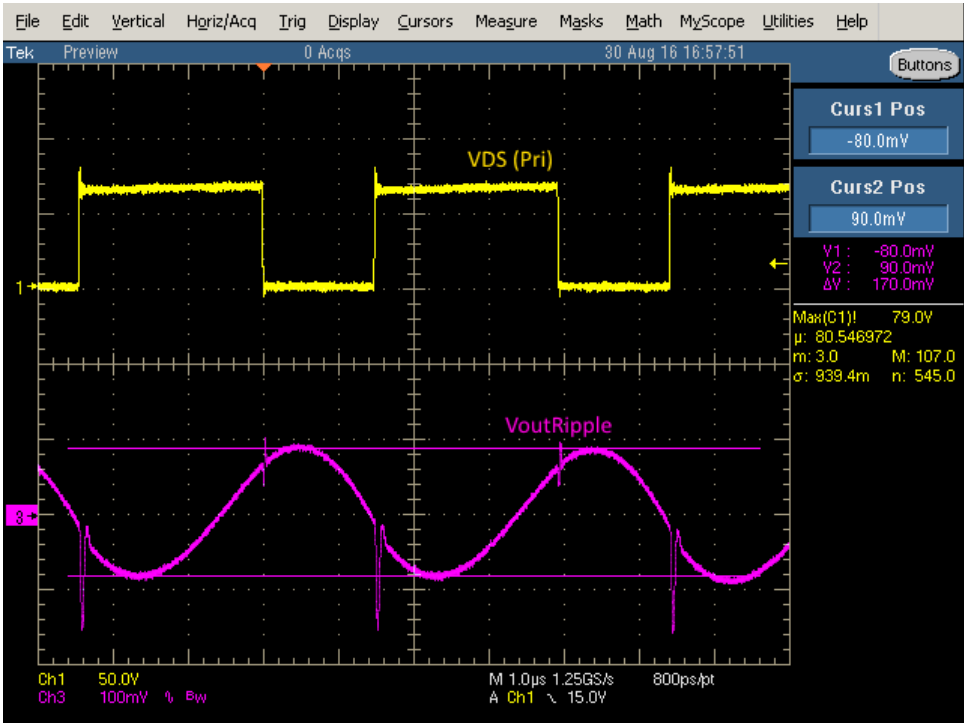


Figure 5. Output Voltage Ripple (Conditions:  $V_{PORT} = 41.2V$ ,  $V_{OUT} = 24V$ ,  $I_{OUT} = 2.7A$ )

## TYPICAL PERFORMANCE CHARACTERISTICS



Figure 6. Load Transient Response (Conditions:  $V_{PORT} = 41.2V$ , Load Step: 1.35A to 2.7A to 1.35A)



TYPICAL PERFORMANCE CHARACTERISTICS

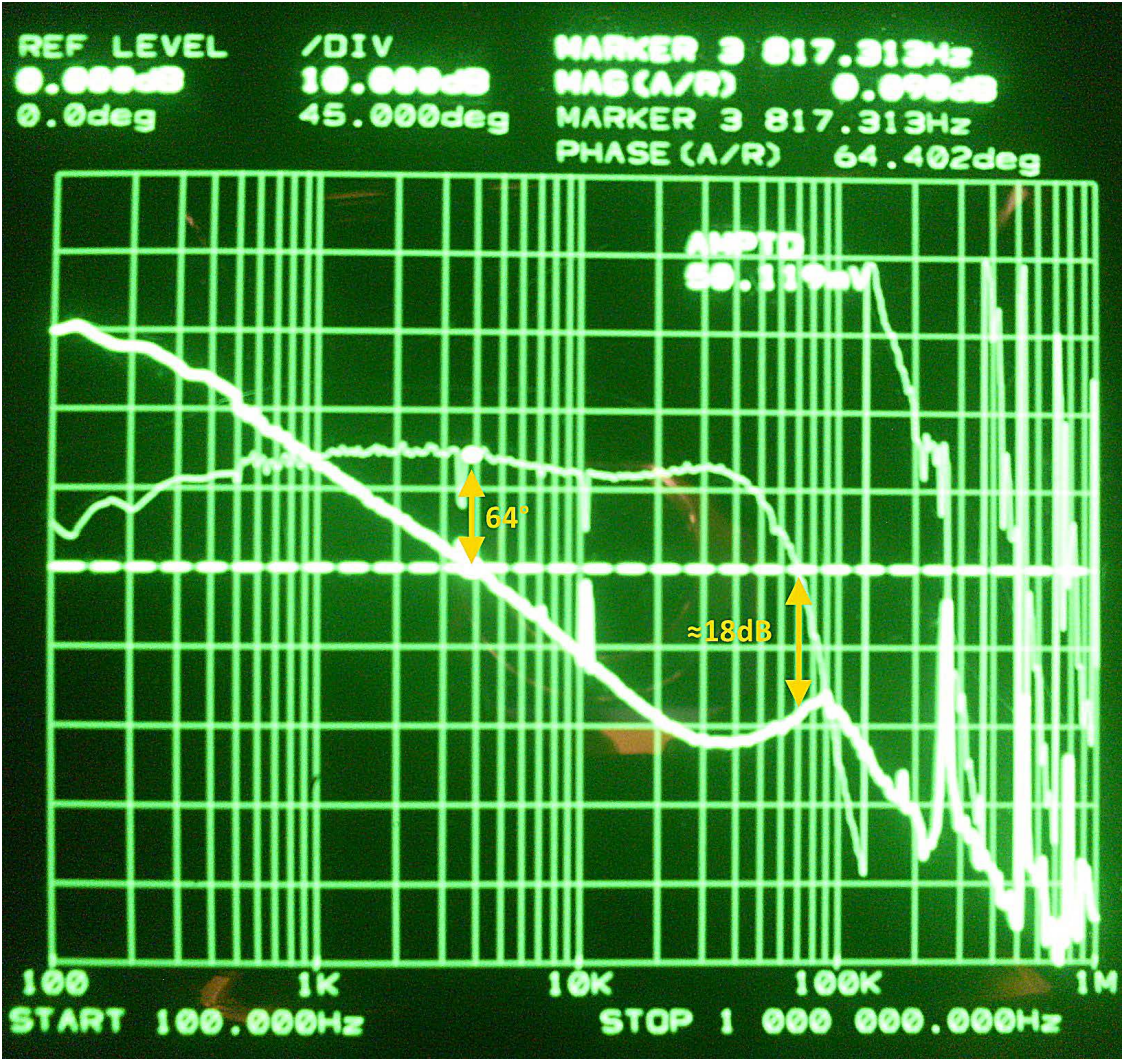


Figure 7. Gain and Phase Margin of the Flyback DC/DC Converter (Conditions:  $V_{PORT} = 57V$ ,  $V_{OUT} = 24V$ ,  $I_{OUT} = 2.7A$ )

| CROSSOVER FREQUENCY | GAIN MARGIN | PHASE MARGIN |
|---------------------|-------------|--------------|
| 3.8kHz              | 18dB        | 64°          |

## QUICK START PROCEDURE

### Power over Ethernet (PoE) Input

1. Disconnect auxiliary supply if it is connected to AUX+ and AUX- inputs of the DC2476A-A.
2. Place and connect test equipment (voltmeter, ammeter, oscilloscope and electronic load) as shown in Figure 8.
3. Turn down the electronic load to a minimum value and turn off the electronic load.
4. Connect the output of the IEEE 802.3bt compliant PSE to the RJ45 connector (J1) of the DC2476A using a CAT5e or CAT6 Ethernet cable. (See Note.)
5. After the LED (D4) on the DC2476A is lit, check the output voltage using a voltmeter. Output voltage should be within  $24.0V \pm 0.3V$ .

6. Turn on the electronic load and increase its load current up to 2.7A. Observe the output voltage regulation, efficiency, and other parameters.
7. Verify  $\overline{T2P}$  response with an oscilloscope as shown in Figure 8. The  $\overline{T2P}$  response to the type of PSE connected to the DC2476A-A is provided in Table 1.

Note: An 802.3bt PSE has not yet been released. In the interim, an LTPoE++<sup>®</sup> compliant PSE (DC1814A-D) may be used to provide power to the DC2476A-A. The LTPoE++ classification will not be 802.3bt compliant, but the PSE will provide a compatible detection and power output. Specifically, the  $\overline{T2P}$  output of the DC2476A-A is different from the behavior stated in Table 1 and will indicate connection to a Type 2 PSE. Otherwise PD behavior will be unaffected.

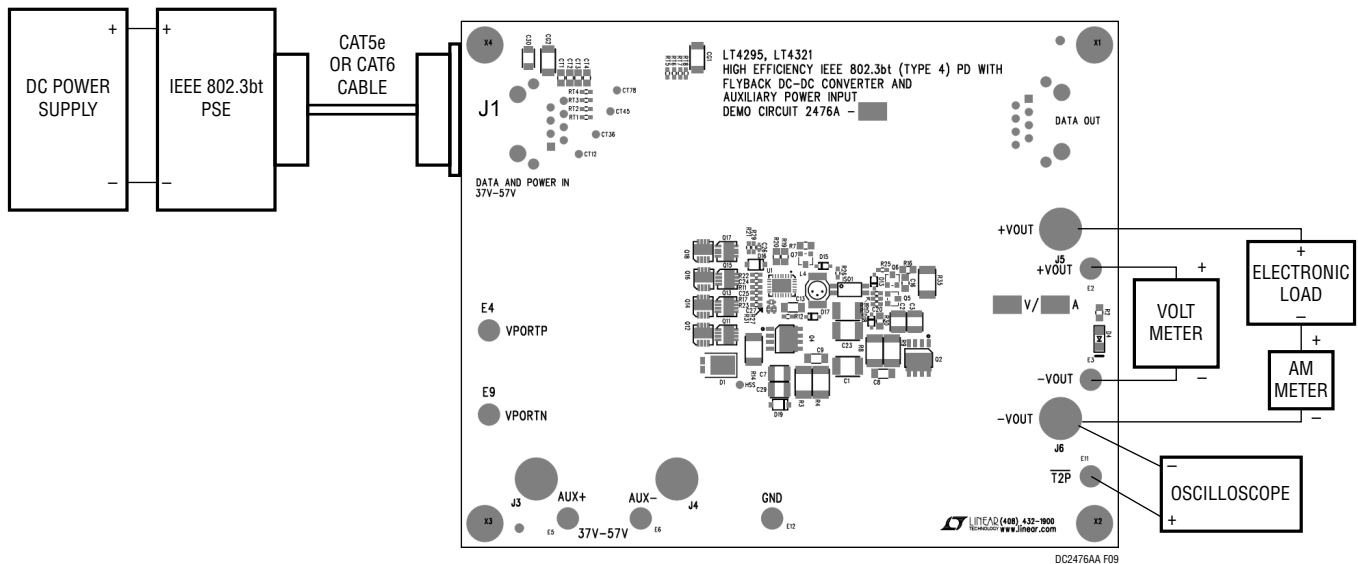


Figure 8. Setup Diagram for PoE Input

Table 1.  $\overline{T2P}$  Response

| PSE          | $\overline{T2P}$ Response                               | Negotiated PD Input Power |
|--------------|---|---------------------------|
| IEEE         | Logic High  | 13W                       |
|              | Logic Low   | 25.5W                     |
|              | 50% Logic High/50% Logic Low, Toggle at 976Hz $\pm 7\%$ | 51W                       |
|              | 75% Logic High/25% Logic Low, Toggle at 976Hz $\pm 7\%$ | 71W                       |
| LTPoE++, 90W | Logic Low   | 71W                       |

## QUICK START PROCEDURE

### Auxiliary Supply Input

1. Place and connect test equipment (voltmeter, ammeter, oscilloscope and electronic load) as shown in Figure 9.
2. Turn down the electronic load to a minimum value and turn off the electronic load.
3. Connect the output of the auxiliary supply to the DC2476A as shown in Figure 9. Turn on the auxiliary supply and set its current limit to 2A. Then increase its output voltage to 48V.
4. Once the LED (D4) on the DC2476A is lit, check the output voltage using a voltmeter. Output voltage should be within  $24.0V \pm 0.3V$ .
5. Turn on the electronic load and increase its load current up to 2.7A. Observe the output voltage regulation, efficiency, and other parameters.
6. Verify  $\overline{T2P}$  response with an oscilloscope as shown in Figure 9. The  $\overline{T2P}$  response during auxiliary power operation is: 75% Logic High/25% Logic Low, Toggle at  $976Hz \pm 7\%$ .

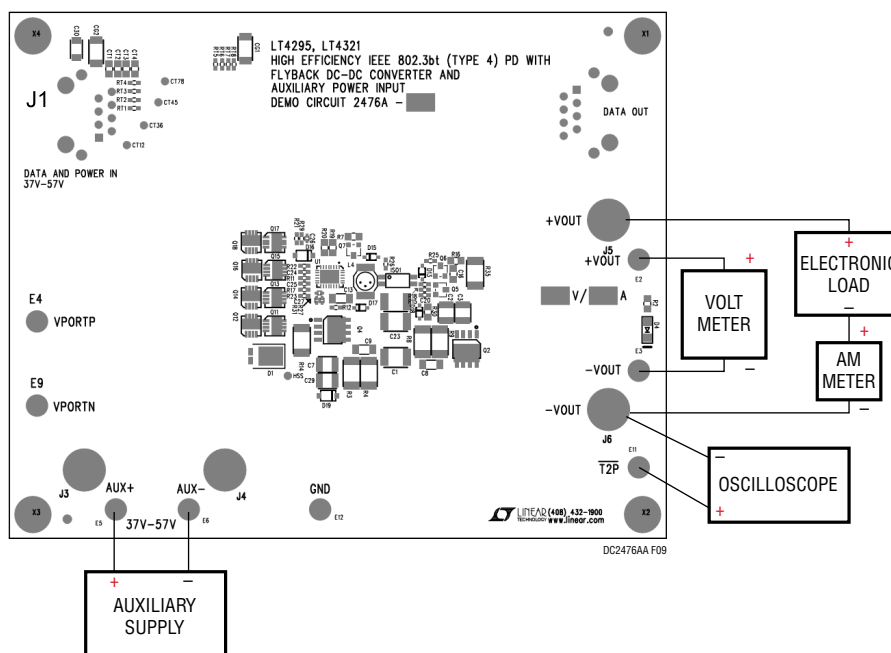


Figure 9. Setup Diagram for Auxiliary Supply Input



## PARTS LIST

| ITEM                       | QTY | REFERENCE                        | PART DESCRIPTION                          | MANUFACTURER/PART NUMBER          |
|----------------------------|-----|----------------------------------|---|-----------------------------------|
| <b>DC2476A General BOM</b> |     |                                  |   |                                   |
| 1                          | 2   | CG1, CG2                         | CAP, CER, X7R 1000pF 2kV 10% 1808         | MURATA, GR442QR73D102KW01L        |
| 2                          | 4   | CT1, CT2, CT3, CT4               | CAP, CER, X7R 0.01μF 100V 20% 0805        | MURATA, GRM21BR72A103MA01L        |
| 3                          | 0   | C1                               | CAP, CER, OPT 2kV 1812                    | OPT                               |
| 4                          | 1   | C6                               | CAP, ELEC, 22μF 100V 10% 8x10.2           | SUNCON, 100CE22KX                 |
| 5                          | 2   | C7, C29                          | CAP, CER, X7R 2.2μF 100V 10% 1210         | MURATA, GRM32ER72A225KA35         |
| 6                          | 1   | C10                              | CAP, CER, X7R 10nF 100V 20% 0603          | MURATA, GRM188R72A103KA01D        |
| 7                          | 1   | C11                              | CAP, CER, X7R 0.047μF 100V 20% 0603       | KEMET, C0603C473M1RACTU           |
| 8                          | 1   | C12                              | CAP, CER, X7R 0.047μF 100V 10% 0805       | MURATA, GRM21BR72A473KA01L        |
| 9                          | 1   | C13                              | CAP, CER, X7R 10μF 10V 10% 1206           | MURATA, GRM31CR71A106KA01L        |
| 10                         | 0   | C15, C18, C19, C21               | CAP, CER, X5R OPT 2kV 20% 1812            | OPT                               |
| 11                         | 1   | C17                              | CAP, CER, X7R 1μF 25V 10% 0603            | MURATA, GRM188R71E105KA12         |
| 12                         | 1   | C20                              | CAP, CER, X7R 2.2nF 25V 10% 0603          | MURATA, GRM188R71E222KA01         |
| 13                         | 1   | C24                              | CAP, CER, X7R 0.1μF 25V 20% 0603          | MURATA, GRM188R71E104KA01D        |
| 14                         | 1   | C26                              | CAP, CER, X7R 100pF 16V 10% 0402          | AVX, 0402YC101KAT2A               |
| 15                         | 0   | C27                              | CAP, CER, X7R OPT 6.3V 10% 0402           | OPT                               |
| 16                         | 1   | C30                              | CAP, CER, X7R OPT 250V 10% 1206           | AVX, 12061C103MAT2A               |
| 17                         | 1   | D1                               | DIODE, SCHOTTKY, PDS5100H 100V POWERDI5   | DIODES INC, PDS5100H              |
| 18                         | 3   | D2, D16, D19                     | DIODE, TVS, PTVS58VS1UR 58V SOD123        | NXP, PTVS58VS1UR                  |
| 19                         | 1   | D3                               | DIODE, ZENER, MMSZ5252BS 24V SOD323       | DIODES INC, MMSZ5256BS            |
| 20                         | 1   | D13                              | DIODE, SCHOTTKY, BAT46WJ, 115 100V SOD323 | NXP, BAT46WJ, 115                 |
| 21                         | 1   | D15                              | DIODE, BAV19WS 120V SOD323                | DIODES INC, BAV19WS               |
| 22                         | 1   | D17                              | DIODE, SCHOTTKY, PMEG1020EA 10V SOD323    | NXP, PMEG1020EA                   |
| 23                         | 8   | E2, E3, E4, E5, E6, E9, E11, E12 | TP, TURRET, PAD150-094 0.094"             | MILL-MAX, 2501-2-00-80-00-00-07-0 |
| 24                         | 1   | ISO1                             | OPTO, TLP291(GR-TP, E)                    | TOSHIBA, TLP291(GR-TP, E)         |
| 25                         | 2   | J1, J2                           | CONN, RJ-45, SS-6488-NF-K1                | STEWART CONNECTOR, SS-6488-NF-K1  |
| 26                         | 4   | J3, J4, J5, J6                   | CONN, BANANA JACK                         | KEYSTONE, 575-4                   |
| 27                         | 1   | L2                               | IND, 4.7μH                                | WURTH, 744316470                  |
| 28                         | 1   | L3                               | IND, CMC, 3.5mH,                          | PCA, EPZ3109G-LF                  |
| 29                         | 1   | L4                               | IND, 100μH                                | COILCRAFT, DO1608C-104MLB         |
| 30                         | 0   | L6                               | IND, OPT                                  | OPT                               |

# DEMO MANUAL DC2476A-A

## PARTS LIST

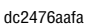
| ITEM | QTY | REFERENCE                              | PART DESCRIPTION                                 | MANUFACTURER/PART NUMBER   |
|------|-----|--|--|----------------------------|
| 31   | 1   | Q1                                     | MOSFET, N-CH, PSMN040-100MSE 100V LPAK33         | NXP, PSMN040-100MSE        |
| 32   | 1   | Q5                                     | TRANSISTOR, PNP, PBSS5140T 40V SOT23             | NXP, PBSS5140T             |
| 33   | 1   | Q6                                     | TRANSISTOR, NPN, PBSS4140T 40V SOT23             | NXP, PBSS4140T             |
| 34   | 1   | Q7                                     | TRANSISTOR, PNP, FMMT723 100V SOT23              | DIODES INC, FMMT723        |
| 35   | 8   | Q11, Q12, Q13, Q14, Q15, Q16, Q17, Q18 | MOSFET, N-CH, PSMN040-100MSE 100V LPAK33         | NXP, PSMN040-100MSE        |
| 36   | 8   | RT1, RT2, RT3, RT4, RT5, RT6, RT7, RT8 | RES, CHIP, 75 $\Omega$ 5% 0603                   | PANASONIC, ERJ-3GEYJ750V   |
| 37   | 1   | R5                                     | RES, CHIP, 8.2 $\Omega$ 5% 0805                  | PANASONIC, ERJ-P6WJ8R2J    |
| 38   | 1   | R6                                     | RES, CHIP, 3.3K 5% 0603                          | VISHAY, CRCW06033K30FKEA   |
| 39   | 1   | R7                                     | RES, CHIP, 20 $\Omega$ 5% 0805                   | VISHAY, CRCW080520R0JNEA   |
| 40   | 2   | R12, R28                               | RES, CHIP, 0 5% 0603                             | PANASONIC, ERJ-3GEY0R00V   |
| 41   | 1   | R13                                    | RES, CHIP, 100 $\Omega$ 5% 0603                  | PANASONIC, ERJ-3GEYJ101V   |
| 42   | 1   | R15                                    | RES, CHIP, 15 $\Omega$ 5% 0603                   | VISHAY, CRCW060315R0FKEA   |
| 43   | 1   | R17                                    | RES, CHIP, 2.00K 1% 0603                         | VISHAY, CRCW06032K00FKEA   |
| 44   | 1   | R18                                    | RES, CHIP, 10K 5% 0603                           | VISHAY, CRCW060310K0JNEA   |
| 45   | 1   | R21                                    | RES, CHIP, 174K 1% 0603                          | VISHAY, CRCW0603174KFKEA   |
| 46   | 1   | R22                                    | RES, CHIP, 107K 5% 0603                          | VISHAY, CRCW0603107KFKEA   |
| 47   | 2   | R27, R31                               | RES, CHIP, 0 $\Omega$ SHUNT 0402                 | VISHAY, CRCW04020000Z0EA   |
| 48   | 1   | R29                                    | RES, CHIP, 52.3K 1% 0603                         | PANASONIC, ERJ-3EKF5232V   |
| 49   | 0   | R32                                    | RES, CHIP, OPT 1% 1812                           | OPT                        |
| 50   | 0   | R33                                    | RES, CHIP, OPT 5% 0805                           | OPT                        |
| 51   | 1   | R34                                    | RES, CHIP, 0 $\Omega$ SHUNT 0603                 | PANASONIC, ERJ-3GEY0R00V   |
| 52   | 1   | T3                                     | XFMR, SMD GATE DRIVE, PE-68386NL                 | PULSE, PE-68386NL          |
| 53   | 0   | T3 (ALTERNATE)                         | XFMR, SMD GATE DRIVE, EPA4271GE-LF               | PCA, EPA4271GE-LF          |
| 54   | 1   | T4                                     | TRANSFORMER, ETHERNET, 749022016                 | WURTH, 749022016           |
| 55   | 0   | T4 (ALTERNATE)                         | TRANSFORMER, ETHERNET, ETH1-460LD                | COILCRAFT, ETH1-460LD      |
| 56   | 0   | T4 (ALTERNATE)                         | TRANSFORMER, ETHERNET, EPG4260S-LF               | PCA, EPG4260S-LF           |
| 57   | 1   | U1                                     | IC, PD & SWITCHER CONTROLLER, LT4295IUF QFN28    | LINEAR TECH, LT4295IUF#PBF |
| 58   | 1   | U3                                     | IC, POE IDEAL BRIDGE CONTROLLER, LT4321IUF QFN16 | LINEAR TECH, LT4321IUF#PBF |
| 59   | 4   | MH1-MH4                                | STAND-OFF, NYLON 0.50" TALL (SNAP ON)            | KEYSTONE, 8833             |
| 60   | 2   |  | STENCILS (TOP & BOTTOM)                          | STENCIL, DC2476A           |

## PARTS LIST

| ITEM             | QTY | REFERENCE      | PART DESCRIPTION                         | MANUFACTURER/PART NUMBER   |
|------------------|-----|----------------|--|----------------------------|
| <b>DC2476A-A</b> |     |                |  |                            |
| 1                | 1   | C2             | CAP, CER, X5R 10 $\mu$ F 50V 10% 1210    | MURATA, GRM32ER61H106KA12  |
| 2                | 0   | C3             | CAP, CER, X5R OPT 50V 10% 1210           | OPT                        |
| 3                | 1   | C4             | CAP, ELEC, 47 $\mu$ F 35V 20%            | PANASONIC, EEE-FK1V470P    |
| 4                | 0   | C5             | CAP, ELEC, OPT 35V 20%                   | OPT                        |
| 5                | 1   | C8             | CAP, CER, U2J 330pF 630V 5% 1206         | MURATA, GRM31A7U2J331JW31  |
| 6                | 1   | C9             | CAP, CER, U2J 220pF 630V 5% 1206         | MURATA, GRM31A7U2J221JW31  |
| 7                | 1   | C16            | CAP, CER, X7R 0.1 $\mu$ F 25V 10% 0805   | MURATA, GRM21BR71E104KA01L |
| 8                | 1   | C22            | CAP, CER, X7R 3.3nF 25V 10% 0603         | MURATA, GRM188R71E332KA01D |
| 9                | 1   | C23            | CAP, CER, X7R 4.7nF 2kV 1812             | MURATA, GR443DR73D472KW01L |
| 10               | 1   | C25            | CAP, CER, X7R 330pF 25V 10% 0603         | AVX, 06033C331KAT2A        |
| 11               | 0   | D18            | DIODE, DIODE INC, OPT 30V SOD323         | OPT                        |
| 12               | 1   | L5             | IND, 1 $\mu$ H                           | WURTH, 744316100           |
| 13               | 1   | Q2             | MOSFET, N-CH, BSC320N20NS3 200V SUPERS08 | INFINEON, BSC320N20NS3     |
| 14               | 1   | Q4             | MOSFET, N-CH, BSC190N15NS3 150V SUPERS08 | INFINEON, BSC109N10NS3 G   |
| 15               | 2   | R3, R4         | RES, CHIP, 51 $\Omega$ 5% 2010           | VISHAY, CRCW201051R0JNEF   |
| 16               | 2   | R8, R9         | RES, CHIP, 36 $\Omega$ 5% 2010           | PANASONIC, ERJ-12ZYJ360U   |
| 17               | 1   | R10            | RES, CHIP, 3.65K 1% 0603                 | VISHAY, CRCW06033K65FKEA   |
| 18               | 1   | R11            | RES, CHIP, 5.23K 5% 0603                 | VISHAY, CRCW06035K23FKEA   |
| 19               | 1   | R14            | RES, CHIP, 15m $\Omega$ 1% 2010          | VISHAY, WSL2010R0150FEA    |
| 20               | 1   | R16            | RES, CHIP, 0 $\Omega$ SHUNT 0805         | VISHAY, CRCW08050000Z0EA   |
| 21               | 1   | R19            | RES, CHIP, 118 $\Omega$ 1% 0805          | PANASONIC, ERJ-6ENF1180V   |
| 22               | 1   | R20            | RES, CHIP, 52.3 1% 0805                  | VISHAY, CRCW080552R3FKEA   |
| 23               | 1   | R23            | RES, CHIP, 36K 5% 0603                   | VISHAY, CRCW060336K0FKEA   |
| 24               | 1   | R24            | RES, CHIP, 51K 5% 0603                   | VISHAY, CRCW060351K0JNEA   |
| 25               | 1   | R25            | RES, CHIP, 20K 5% 0603                   | PANASONIC, ERJ-3EKF2002V   |
| 26               | 1   | R26            | RES, CHIP, 4.7K 5% 0603                  | YAGEO, RC0603JR-074K7L     |
| 27               | 0   | R30            | RES, CHIP, OPT 5% 0805                   | OPT                        |
| 28               | 0   | R35            | RES, CHIP, OPT 5% 2010                   | OPT                        |
| 29               | 1   | T1             | XFMR, PWR TRAN, EPC3630G-LF              | PCA, EPC3630G-LF           |
| 30               | 0   | T1 (ALTERNATE) | XFMR, PWR TRAN, 750316231                | WURTH, 750316231           |
| 31               | 1   |                | FAB, PRINTED CIRCUIT BOARD               | DEMO CIRCUIT 2476A         |

## SCHEMATIC DIAGRAM





# DEMO MANUAL DC2476A-A

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## DEMONSTRATION BOARD IMPORTANT NOTICE

Linear Technology Corporation (LTC) provides the enclosed product(s) under the following **AS IS** conditions:

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**Please read the DEMO BOARD manual prior to handling the product.** Persons handling this product must have electronics training and observe good laboratory practice standards. **Common sense is encouraged.**

This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact a LTC application engineer.

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